**NWX NASA JPL Audio**

**Moderator: Michael Greene**
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Coordinator: Welcome and thank you for standing by. At this time all participants are in a listen-only mode until the question and answer session of today's conference. At that time you may press star 1 on your phone to ask a question. I would like to inform all parties that today's conference is being recorded. If you have any objections you may disconnect at this time. I would now like to turn the conference over to Mr. (Dave Prosper). Thank you, you may begin.

(Dave Prosper): Okay, thanks (Nicole). And hi everyone and welcome. I am here at the NASA Night Sky Network from the Astronomical Society Pacific here in San Francisco, California and I'm really excited to present this teleconference with our awesome guest speaker, Dr. David Williams from NASA's Dawn Mission Vesta and Ceres.

But before we get started I want to make sure that you can all view the presentation and slides. This time we have them in PDF aka Adobe Acrobat format. And so if you don't have the slides up in front of you you can download them at our special URL bit.ly/dawnnsn - that's bit.ly/dawnnsn and if you have any problems along the way please feel free to email us at night skyinfo@astrosociety.org.

And so if this is your first teleconference or 50th with us, welcome. Just follow along with the slides and we're going to make some time for a brief Q and A at the end of this talk. Right before we begin I just want to have a brief minute for the latest Night Sky Network news for our club members.

We are currently prepping and shipping toolkits to our clubs who have not received all of our toolkits and who have logged events for the second quarter of 2014. We're still collecting responses as well for our Future of Amateur Astronomy survey. You can find that survey at bit.ly/2014astrosurvey. And that's also one of the main news items at our main site. And we want to - we want you to tell us your needs and who you are currently serving in your outreach so we can better serve you and your clubs here at the NSN. And, again, that survey link is at bit.ly/2014astrosurvey.

And speaking of which we have another round of bug fixes coming to the site as well. We fixed many problems relating to your (unintelligible) have enabled a handy opt-out feature for that location as well. And we've greatly sped up the calendar and have made some additional tweaks rendering and speed. And we're hoping that roll-up these fixes to the main site in the next couple of weeks, which will be just in time for you to log your clubs events to qualify for toolkits and prizes for the third quarter of 2014.

So, now we have a rather in depth presentation that I'm trying to keep our intro brief so we'll have time to jump in and have a Q and A at the end. So it's my great pleasure to introduce our speaker, Dr. David Williams of NASA's Dawn Mission who will be speaking on Asteroids, Ion Propulsion and NASA's Dawn Mission to Vesta and Ceres. We'll have a brief bio for Dr. Williams who is a Associate Research Profession in the School of Earth and Space Exploration at Arizona State University in Tempe, Arizona. Dr.

Williams is the Director of the Ronald Greeley Center for Planetary Studies, the NASA Regional Planetary Information Facility at ASU. He's also the Director of the NASA Planetary Aeolian Laboratory at the Ames Research Center in California.

Dr. Williams is currently performing research in volcanology and planetary geology with a focus on planetary mapping, geochemical and remote sensing studies. And his research has included computer modeling of seismic wave propagation through planetarium interiors, visible and near infrared spectroscopy of the lunar surface, planetary geologic mapping of the satellites of Jupiter, the planet Mars and the asteroid Vesta. That's why we're here.

A computer modeling of the physical and geochemical evolution of lava flows in a variety of planetary environments and the petrologic study of lava samples from Mount St. Helens. He was involved with NASA's Magellan Mission to Venus and the Galileo Mission to Jupiter. He is a Co-Investigator on the European Space Agency's Mars Express orbiter mission, and he was a Participating Scientist on NASA's Dawn Mission to asteroid Vesta.

And in 2014 David was elected to become a fellow of the Geological Society of America and in 2014 asteroid 10,461 D-A Williams was named in his honor. So Dr. David Williams if you would like to begin I can hand this over to you.

Dr. David Williams: Thank you very much. Can you hear me okay?

(Dave Prosper): I hear you loud and clear.

Dr. David Williams: Okay, well it's a pleasure to participate in the telecom for the Night Sky Network. I do an awful lot of presentations here in my hometown area of

Phoenix, Arizona to the Astronomical Clubs that are around here so it's a pleasure to be able to talk to some Astronomical Clubs throughout wherever your network reaches.

So if you'll turn to the slide packet you should be on slide one with the title of the presentation, Asteroids, Ion Propulsion, and NASA's Dawn Mission to Vesta and Ceres and you should see a image mosaic of Ceres on the screen. So going ahead to slide number two you should see a slide that says how do we explore the solar system with a question mark. And I usually like to start my presentations for groups that try and communicate and answer questions about, you know, how we explore the solar system with robotic spacecraft.

We do what we call a phased approach. We do what's technically possible, what we have the engineering skills to build, we do what's affordable, but we have the money to do. So we do the easy missions first. We accomplish them successfully then we go on to the more complex missions. And as you go down the list of bullets there you see the missions in terms of increasing difficulty and complexity.

The easiest to do is a Planetary Fly-by. You launch a spacecraft that flies by a planetary body and takes pictures and transmits that back to earth. The next hardest thing to do is to do an Orbiter Mission - one that can actually slow down and get into orbit about a planet, but the goal of Orbiter Missions are to get a global assessment of the surface because in an orbit you're able to gather data as the planet rotates underneath you and that allows you to get the global geologic context of a planet.

So once you understand the global context from Orbiter Missions then you actually want to land on the surface and there's a variety of ways you can land. You can have hard landers that take images as they descend, but then when they hit the ground their instruments are broken. So more often than not you want to use soft landers, something that uses parachutes or thrusters or airbags to slow down so it lands on the surface so your scientific instruments can actually collect data right there at the landing site. However, once you have data at one location you tend to look on the horizon and you see something interesting off on the horizon.

So then, you know, you wish you had some form of mobility and the next type of robotic mission is called a rover. Planetary Rovers give you mobility on land or if it's a body that has an atmosphere you might be able to travel through the atmosphere. The next hardest thing to do is a Robotic Sample Return where you actually collect a sample of rock or soil or air or ice and put it into a container that you then return to the earth where you can study things more effectively in our laboratories. And then at the very bottom the hardest and most expensive thing to do are human missions where you send crews to orbit and then land on other planetary bodies.

So if you go to the next slide, slide three, you should see a chart of solar system exploration where across the top you see the different modes of robotic exploration calumniating in human missions. And then if you go down the Y axis you'll see the major bodies of our solar system from the planet Mercury all the way out to Pluto. And for the purpose of this talk Pluto is a planet no matter what the IU says about that.

So you see there we have telescopic observations of everything, of course, because we had to do that to discover them. We've had flybys of all of the major planets of the solar system except Pluto, however, we do have a space craft called New Horizon that is on its way to Pluto and will do a Pluto flyby in July of 2015. So we'll actually be able to characterize Pluto. Is it a planet?

Is it more like an outer planet satellite? Is it more like a (quaffer) belt object, etcetera.

As you can see as you move across the chart we've had orbiters to most of the inner planets and you see DAWN highlighted in pink because it was the first Orbiter of a main belt asteroid. You see Rosetta highlighted in orange there because that is happening right now. A mission to orbit a comet and it's going to have a German built lander that's going to land on it in November of this year. You see the yellow things - these are our missions that are in being proposed, but have not yet been funded and the one that's there for Juice, that's the Jupiter Icey Moons Explorers, that's going to be the European Space Agency's first Mars robotic mission, which will be an Orbiter of Ganymede, the largest moon in the solar system orbiting Jupiter.

Landers, we've had landers on Venus, robotic landers on the moon, the Viking and other landers on Mars and I mentioned about Rosetta going to land on a comet later this year. You see rovers, the bigger balloons that the Soviet Union made into the atmosphere of Venus. Their Lunokhod rovers that existed on the moon in the 1970s (unintelligible). We've had our very successful program of rovers on Mars, of which the latest MSL refers to the curiosity rover.

Sample returns - the Soviet Union did a robotic sample return from the moon in the 1970s. We've had samples return from comets and asteroids and solar wind material and we're at the beginning of the planning stages for a Mars sample return mission in the next decade and, of course, the only place that humans have been is to the moon with the Apollo program. So what I like to say is we want to completely fill in this chart, completely explore the Solar System all the way up through human missions then we'll be able to living Star Trek and boldly going where no one has gone before.

Moving on to the next slide with that preamble, the outline of the talk I'd like to give today is to tell you a little bit about asteroids -- what are they, where are they located, why do we care about Ceres and Vesta? I'll tell you a little bit about Ion propulsion because it's the driver that has enabled the dawn mission and some aspects about how it works. And then I'll go through a brief review of the NASA Dawn Mission itself -- the objectives, the instruments and how it operated and the results we've obtained so far including a preview of what we can expect in Ceres next year and then we'll go to the Q and A.

So asteroids - you should be on slide number five. Asteroids, what are they? Well they're basically minor planets. They're the remains of materials that did not actually coalesce coolest to form a planet. Most of them are less than 500 kilometers in diameter. They're mostly irregularly shaped and they tend to be composed of silicate rock, dust and volatiles - and volatiles in this context means ices like water ice. The image that you see on the right of the slide is Lutetia, which was imaged on Rosetta on its course to the outer solar system.

Most asteroids are located in the main belt located between the orbits of the planets Mars and Jupiter. There's a population of asteroids we call Trojans at the Lagrange points of Jupiter's orbit about the sun. There's another population called Centaurs located between the orbits of Jupiter and Neptune. But perhaps the most famous or infamous asteroids are the NEAs, the Near-Earth Asteroids of which you see there are several types there. These are the ones that come very close to Earth. They can cross the Earth's orbit

There's about 4700 of these potentially hazardous Near-Earth Asteroids. You might recall in last year, 2013, that we had the fly-by of asteroid 2012 DA14 was one of these Apollo asteroids, but on that very same day there was the surprise of the Chelabinsk meteor that exploded over that Russian city. And then we had another one in February of this year too as you see there.

If you go to the next slide, slide number six, this is just some information about the 2012 DA14 Asteroid Flyby in February of 2013. It was record close approach for an object of it’s size. You can see the speed at which it came by. What made this interesting is that this particular asteroid came in above orbit of the ISS and low orbit satellites, but below the orbit of our geosynchronous weather satellites. It came in from south to north so it wasn’t visible from the United States. This asteroid was about 45 meters long rock asteroid. So it’s about to be the same size as the impactor that formed Meteor Crater in Arizona, which is a 1200 meter diameter, 170 meter deep, crater, which you see imaged there at lower right.

If that asteroid had hit it would have had the destructive energy of 2.4 megatons and destroyed everything within 50 miles of the impact site, however, it was not big enough to end civilization. You might recall the Chicxulub impact that was discovered in the Yucatan Peninsula. That was formed by a 10 kilometer diameter impactor produced a 180 kilometer crater and that’s the one that finally killed off the dinosaurs 65 million years ago.

Next slide, slide seven is about the Chelyabinsk meteor. You see some images from when it was observed back on February 15 of 2013. This meteor came from the Main Asteroid Belt and it was the largest meteor strike in a century since the 1908 Tunguska event. It entered the atmosphere at about 40,000 miles per hour. It was about 17 meter in diameter.

Now this one came in west to east so we know it is not related to the 2012 DA14 event of the same day. It airburst 12 to 15 miles above ground with a 500 kiloton blast. Shock waves spread out from the blast and had a downward shock wave that shattered windows over 200,000 square kilometers. There were about 1000 injuries in Russia. 4000 buildings destroyed and an estimated damage of 33 million. So there's approximately 53 meteorites that were found at the time shortly after that and if you go to the next slide you can see some example images of the damage.

You can see the lake where they retrieved the largest sample. That's a particular type of asteroid called an ordinary chondrite and we have samples of that meteorite here at ASU and many other places.

So if you go on to slide number nine you can see the continuous of the description of asteroids. There are basically 14 types of asteroids and they are classified based on the telescopic spectra. The largest class are C, the carbonaceous type. There's the S-stony type, D and P dark, primitive types. M is metallic, the iron meteorites in asteroids and V type for Vesta is unique because it's made out of basaltic minerals, those that are produced by volcanic lava flows.

So we know a lot about some asteroids because their spectra can be compared with meteorites in the laboratory and we know that asteroids are probably rocks that never coalesced into a planet. The Main Asteroid Belt was just too susceptible to gravity from the giant planet Jupiter that it never allowed the planets to form in this location.

Next slide, number ten, you'll see is some images of a particular type of meteorite that are called HEDs and that stands for howardite, eucrite and diogenite." And these particular meteorites come from Vestas. They've been very helpful in understanding the data from the Dawn Mission and basically howardites are an impact (unintelligible). Sort of like a sedimentary rock made from fragments of the other two types - eucrite, which is like the basaltic minerals from lava flows and then diogenite are from deeper in the interior of their parent body from the interior of Vesta and together they make up this (unintelligible) that comes from Vesta.

So if you'll go to slide 11 - this is just a summary of spacecraft exploration of asteroids and most of the asteroids that have been visited by spacecraft have not been the primary targets. They've been just flybys on way to other locations and the first two that were imaged 951 Gaspra and 243 Ida were the targets of the Galileo during its inter-solar system flybys before getting out to Jupiter.

You can see the first one Eros, the first Orbitor of a Near-Earth Asteroid that was actually able to touch down on the surface. The asteroid, you know, Itokawa, that was the target of the Japanese Hayabusa mission and that returned the first sample. And then finally the Dawn Mission to Vesta and Ceres and the next major robotic mission to an asteroid is the OSIRIS-REx mission, which will be visiting the asteroid Bennu launching hopefully in September of 2016.

Moving to slide twelve, you see this montage made by the Planetary Society where you see all of the asteroids that have been imaged by spacecraft prior to the Dawn arrival of Vesta. Below the white diagonal line are the comets that have been visited up to that time. And you can see these are very irregular, rocky bodies. If you look closely at Lutetia, 21 Lutetia, you'll see boulders on the surface, impact craters, you see some lineation's on there perhaps evidence of ancient (unintelligible), but you see the irregular nature of these bodies.

Now Lutetia looks pretty big compared to some of the other asteroids, but if you go to the next slide, number 13, you'll see the planets Mars, Mercury, the moon - all to the same size scale with the two largest asteroids, Ceres and Vesta, put in there. So those asteroids are quite small on a planetary context.

Now on slide 14 you see Vesta, an image of Vesta, from the Dawn Mission compared to several other asteroids. You see 21 Lutetia there. So Vesta has been the largest asteroid visited to date. And if you go to the next slide, number 15, you see Vesta compared to Saturn's moon Enceladus. It's a little largest than Enceladus and slide 16 shows Vesta in comparison to one of the western states in our United States, New Mexico. And you see it's basically an asteroid that's the size of a state. It's a very very large object.

So if you move on to slide 17, this is sort of a summary of why we care about Ceres. Ceres was the first asteroid discovered. It's roughly spherical body with a radius of 468 kilometers, discovered by Giuseppi Piazzi in 1801. Originally classified as a planet, then an asteroid and then is currently classified as a Dwarf Planet. It orbits at 2.76 AU. It takes about 4.6 years to go once about the sun. It rotates on an its axis in about 9 hours.

Now Ceres is interesting because it's a C type asteroid. It's got carbonaceous material, it's relatively low density, low porosity, but telescopic spectra shows that it is a primitive body that has the spectra of water in some form on its surface. These could be phyllosilicates clay minerals or perhaps there's an ice covered body that's covered in (regelate). We don't know now, but we will pretty soon. Those images are the best images of Ceres from the Hubble Space Telescope and Dawn will arrive at Ceres, actually the slide needs to be updated. It should be more around March 5, plus or minus a week because Dawn is getting there a little bit quicker.

The next slide, number 18, is about the asteroid Vesta. Vesta was the fourth asteroid discovered and you can see in that Hubble image there it's not actually a sphere. It's more of a tiaxial ellipsoid. Radius is given there. It was discovered by the German H.W. Olberes in 1807. It's closer than Ceres. It orbits at 2.36 AU and has a year - about the sun of about 3.6 earth years. It rotates on it's axis in 5.3 hours.

So Vesta is a V type asteroid and the Spectra indicates basaltic minerals. The minerals you would see in lava flows like what erupt in Hawaii. And the Spectra, as I mentioned earlier, correlates with the HED family of meteorites. So the idea is that if you - that Vesta at one point had volcanism on the surface and that is from heat generated in it's interior, which means it probably differentiated or separated into a crust, a mantel and a core.

It's a little bit more dense. Low porosity and no evidence of water on the surface. So Vesta, as you see there, imaged by Hubble and the Dawn Spacecraft arrived there back on July 16, 2011. So how did Dawn get to Vesta? Well, let's take a little bit look at space flight.

On slide number 19 you see a photo of the launch. Dawn was launched by a conventional chemical rocket back on September 27 of 2007, but the Dawn spacecraft had something else on it - it's called Ion Propulsion. And if you go to the next slide, number 20, I'll tell you a little bit about spaceflight.

Most of the spacecraft that travel from Earth to other bodies in the solar system use chemical propulsion. You burn some sort of a fuel to fire your engine and it takes quite a bit of fuel to get where you're going. It uses something called a Hohmann transfer orbit where you burn your fuel to increase or decrease your velocity, your delta V, to get to your new orbit. However, the Dawn Mission is different and this is the reason why.

The goal of the Dawn Mission is to orbit two asteroids in the main belt, Vesta and Ceres, however, Dawn is a NASA discovery-class or small mission, which is cost-capped at $466 million. To get to Vesta alone using conventional chemical propulsion would have required 5,400 pounds of chemical propellant and a much larger launch vehicle making it too expensive to do for the small class robotic mission.

So instead the team decided they wanted to use new technology to accomplish the science goals of the mission so they took advantage of a technology called Solar-electric ion propulsion, which was space-rated on some earlier missions. And it uses a spiraling orbit to get to Vesta and that's what the graphic at lower right is showing. You basically launch from earth and you continue in orbit around the sun and you just keep going as you apply the ion engine and that continuous burn - that's where you use the blue does on the lines there - allows you to increase your momentum and continually move outward as you spiral around the sun until you get to your target. So it's actually the ion propulsion that enabled the Dawn mission to be able to accomplish this goal.

Now slide 21 asks the question, what does an Ion-Powered Spacecraft look like? Well, if you're like me and a fan of the original Star Trek series on slide 22 you might remember the episode (unintelligible) and on slide 23 we saw what an Ion-Powered Spaceship looks like. Or if you're fans of the Star Trek re-mastered on slide 24, that's what the Ion-Spaceship looks like. Or if you're a fan of Star Wars and you prefer that then, you know, we're all familiar with what the Ion-Powered Spaceship in that particular movie series looked like. But if you're interested in what it actually looked like, on slide 26, you see a picture of the ion engine down there at lower right in a graphic explaining how it works.

How does solar-electric ion propulsion work? Well basically the solar panels on the spacecraft generate electricity to power the spacecraft and the spacecraft contains Xenon, an inert gas, and they use the electricity to ionize and remove one electron per atom of Xenon. 1000 volt electric field is supplied to those ions and it accelerates them up to about 40,000 kilometers per second - that's 89,000 miles per hour. And the reaction force from expelling these ions produces the propulsion at 10x's the speed of chemical rockets.

So a spacecraft with ion propulsion can carry far less propellant to accomplish the same job as a spacecraft using regular chemical propulsion. The system uses only about 3.2 milligrams per second so 24 hours of continuous thrusting of one of these ion engines would only expend about 10 ounces of fuel, however, the price for using this type of technology is that it takes a long time to go where you need to go. The acceleration of the Dawn spacecraft is 7 meters per second per day, which translates as 15 miles per hour per day or in other words the Dawn spacecraft can accelerate from zero to 60 miles per hour in four days. So very very slowly compared to say the internal combustion engine on your car when you want to go zero to 60.

However, the advantage is when you have time on your side if you run one of these ion engines over five years of total thrust time Dawn's effective (delta-v) is 11 kilometers per second or 24,000 miles per hour. This is the same as an entire three stage Delta rocket with nine solid rocket boosters. So if you could fire you ion engine for a long time you can gain quite a bit of change of momentum to go where you're needing to go.

I'll just quickly mention on slide 27 the rocket equation and this compares the thrusting capability evaluating the different types of engines and you notice in the very bottom there the ion engine on Dawn, even though it has the very

very low thrust, is a very very high specific impulse and I'll let you look at that at your leisure at some point. We'll move on to slide 28.

This just shows some key points about the spacecraft and you see a diagram of it with its solar panels and this is just some facts about that. I won't go into detail about this, but we'll move on to slide 29 - some of the Dawn mission firsts

Dawn's first mission to Vesta and then to Ceres, so two bodies in the solar system. It'll be the first robot spacecraft to orbit two Solar System bodies. It'll be the first mission to visit a protoplanet. First prolonged visit to a main belt asteroid. First visit to a draw planet. It'll get to Ceres in actually march of 2015 and it's had the largest propulsive acceleration of any spacecraft. It also has the largest wingspan of any NASA interplanetary mission prior to the launch of Juno and Juno is the Jupiter solar powered orbiter, which will get there in 2016.

Moving on to slide 30 - I'll now go in and talk about the Dawn mission specifically. I've talked about asteroids, I've talked about how we, the Dawn mission, is accomplishing it's goals through the ion propulsion. Now it's about the Dawn mission itself.

The objective is to determine what the role of size and water in determining the evolution of planets. As I mentioned earlier Ceres is large and wet, Vesta is small and dry. So the science drivers for the mission is to try and capture the earliest moments of the origin of the solar system and understand how these two very different bodies have formed and why they followed a very different evolutionary path to give us insights on how asteroids, the building blocks of the terrestrial planets, formed.

If you move on to slide number 31, you see the mission itinerary from launch in 2007. Dawn did a Mars gravity assist in February of 2009. Onto Vesta and then onto Ceres and in each target Dawn will take color photographs, produce a topographic map, map the elemental abundance, the mineralogical composition and the gravity field.

Slide number 32, this is something that just to inform you about that to declare a mission a success you have to accomplish what is called the level one science requirements and these are the goals or things you must accomplish in order for your mission to be considered successful and those are requirements for the Vesta encounter. To determine the bulk density, the spin axis, image 80% of the surface, obtain a topographic map of the surface, spectral, map the elementary abundance, the gravity field, etcetera. And we did accomplish that you can see for Vesta.

On slide number 33 you see the instruments. There are basically three remote sensing instruments on the Dawn spacecraft. A German built framing camera an Italian built visible and infrared spectrometer and a USA built gamma ray and neutron detector. The framing camera was built by the Max Plank Institute for Solar System Research in Germany and is operated with the support of the German aerospace center. That’s what DLR stands for. And you can see that picture of me with the engineering model of the framing camera. So you can see it’s not a huge instrument.

There’s two of those redundant cameras on the Dawn spacecraft, but the framing camera images the surface looking at the morphology or the shape of the planetary surface, the albedo, or bright differences and can image it in color. And from repeated coverage of the surface with this camera you can get stereo imaging and that allows you to produce something called a digital terrain model. It allows you to determine the topography of the surface.

The visible and infrared spectrometer (VIR) is built by the National Institute of Astrophysics in Rome, Italy and operated with the help of the Italian Space Agency - that's what ASI is. It measures the reflected sunlight and emitted thermal radiation from the surface. It has 850 spectral bands between 0.2 and 5 microns. And this instrument allows us to extract mineralogical signatures and thermal properties of surface materials.

And the GRaND, which stands for Gama Ray and Neutron Detector was built by Alamos National Laboratory in New Mexico and is operated by the Planetary Science Institute. And that's what measures the elementary abundance of the surface. The Gama rays that are generated by cosmic ray impacts and solar flares excites the surface and they produce gamma rays and that has a unique signature related to the different elements that make up surface.

And then, finally, you can use the spacecraft itself for a gravity science experiment. You can assess the gravity of a body by looking at the variation in radio waves as the space flies over the surface and you can measure the Doppler shift very precisely and that allows you to get insights about the gravity of the body. And then you see the pictures of VIR and GRaND over there.

So moving on to slide number 34 - it's just sort of the timeline and this just describes how we studied Vesta and how we will study Ceres using a similar approach. There's different phases of the mission. There's the approach phase as you're closing in. Then we do a survey orbit at relatively high altitude and then we drop down to what is called the high-altitude mapping orbit. Then move down to the low altitude mapping orbit and because when we arrived at Vesta the northern hemisphere was in darkness after the end of the low altitude mapping orbit we boosted ourselves back up and we spent a little bit of time up there to finish imaging the North Pole, which was lit up by then before we departed back on September 5, 2012. And this diagram that's on this particular slide is just showing the various mission phases for Vesta, the Vesta operations and then the timeline where the red bar is where we're at where you see we're in cruise thrusting and we're on our way to Ceres.

Moving on to the next slide, this is just an example of the orbits here and it describes why we do these different orbits. The approach phase, when we got better Hubble resolution was to search to make sure Vesta didn't have any moons. We know that asteroids can have moons because we discovered it with the Galileo mission back in the 1990s and we want to make sure Vesta didn't because we didn't want to take a chance with colliding with one.

Once we verified that there weren't any then we went into the survey orbit and you can see the image resolutions and the VIR resolutions for that phase and this was allotted to get our global assessment of surface features and identify in general the areas we wanted to focus on, which when we dropped down to the high-altitude mapping orbit that's where we got our higher resolution images to basically build our topographic models. And in this case focusing on the South Pole, the southern and mid-latitudes.

When we dropped down to the low altitude mapping orbit that gave us our highest resolution images and that also enabled the grand instrument to get it's best quality elemental abundance data. And then back up as I said to the second high altitude mapping orbit to image the mid to northern latitudes. And the graphic there just shows the orbit elevations and as you can see there.

So if you move on to slide 36 and it says approach rotation characterization - this is actually a movie, but in lieu of that I just dropped in four different views of Vesta. The one in upper left shows you equatorial view where you can see the actual equatorial ridges that are produced as a response to the giant impact that we've identified occurred at the South Pole. The one on the upper right shows you the snowman craters - I'll talk a little bit more about that. The one at lower left shows a big bump sticking out right in the middle and that is a continent size region on the surface. They call that (staliotera) and then the one that looks the most round is the one at lower right and that's actually looking straight on the South Pole and you're looking right down at the base of the giant impact crater. Actually, two giant craters with a central peak that it caused why Vesta is not round. It's been misshapen because of these giant impacts.

Slide 37 is just a color view from an approach movie and you can see there are color variations on the surface. You see the snowman crater at left and that big bump, the piece of original Vesta crust there, but you see the bright lines of fresh craters. You see some dark lines, some dark material. You see some radish material on the side over there and you see sort of the bluish material indicating the excavation down into the mantel at the South Pole.

So slide 38 and 39 just mention some of the science papers that we've done based on analysis of the Vesta data. So I'll just, you don't need to read that or you can read it later at your leisure. On slide 38 and now on slide 39 this is just describing some of the great work we've done. So if you go to slide number 40 it says Vesta's geology and I'll take you through a tour of what we discovered in Vesta.

Go to slide number 41 and you can see a color coded map of Vesta's topography. And you can see there it's color coded for service elevation so blues are low elevations, basins, the bottoms of impact craters and the reds are higher elevations. And you see sort of a - like the outlining of a region with a depression in the middle at the bottom, but with a little mountain type down there that's a central peak and you see right there in the just right of center right at the 180 degree east you see this large high elevation fragment. That's a piece of the original crust we call the (stalieotera). You should be able see the snowman crater right next to it.

But you can also see these equatorial ridges that go east west right about the equator just south of it there. And then you also see a set of ridges that are going sort of northwest southeast toward that giant blue splotch there at right. And that just shows you that topographic variation on the surface.

The thing that's interesting about Vesta is that it's topography to radius relation is much higher than on the moon or mars. So that means that Vesta is a very hilly and slope intensive environment. If you go on to slide number 42 this just shows you all of the main features on the surface. You know, every planetary body in the solar system uses an IAU approved paradigm for naming features and for Vesta the names of all the craters are named after Vestal virgins and famous Roman women and then famous Roman locations or holidays are used to name the other types of features.

As you move on to slide 43 the key geologic results - impact cratering is the dominant geologic process that has modified Vesta's surface. There's craters on all size scales there. We see the extensive steep slopes are the result in many mass wasting deposits or what we would call landslides and including producing these very unusual features we call bimodal craters. In B1, the center image on the slide, shows you one of these where you have a steeper well-defined upslope rim on a crater, but the lower rim is actually less well-defined is because (unintelligible) has fallen back on top of it.

And slide number 44 shows you what I mean by that. You see when you have an impact on a steep slope you can preserve a better rim upslope, but then downslope you're covered by (objecta) and that makes sort of a softened appearance. So we see that quite a bit on Vesta more so than we've seen any place else.

Slide number 45 shows the south polar mountain and this is the central peak of the large impact that occurred at the South Pole. And you can see in profile there it's taller than the island of Hawaii going from the sea floor. It's not quite as tall as Olympus Mons, the largest yield volcano in the solar system on the planet Mars, but it is a pretty significant central peak.

Now, if you move to the next slide you can see a couple of images showing that central peak within that south polar crater. The colorized view you can see the depression around the rim and then the central peak in the middle. If you look at slide number 47 when you look straight down on it you can see the Rheasilva Basin where we've outlined it with a circle. That's the youngest largest crater there, however, there's evidence of an older crater - we named it Veneneia and you can see it's also - it's partially filled in by the younger crater, but it's evidence is still there.

Now probably the most significant finding of the mission, in my opinion, is exemplified on slide number 48. And what we did was when we saw these ridges - these equatorial ridges and white in those northern ridges in red. We plotted them as planes through a sphere and then when you plot the poles of those planes they tend to correlate with the centers of these two bases at the South Pole. So these troughs, these ridge trough systems that we see on Vesta, must be some sort of a tectonic response to the formation of these two basins at the South Pole.

If you move on to the next slide, number 49, you can see it's actually upside-down, but you see a view of the snowman crater - the three craters that just happened to occur in a line like that, but they've some interesting material in them. Inside the largest crater, which named (Marcia) or (Marsha) in the Italian.

We discovered this unusual pitted terrain and when you look at it in the Dawn images it looks very similar you can see on slide 50 to the image - two images in the lower right is similar terrain on Mars in that Martian terrain is thought to be some sort of a de-volatilization where you have sub-surface or commentary ice that is effected by heat source - perhaps the heat from the impact and it causes that material to devolatilize and it produces those pits. The implication of course is well that there was probably buried ice or something within the crust of Vesta when the (Amartia) crater formed.

If you look at slide 51 you see the view of the North Pole that we got at the end of the mission and slide 52 is a color coded version of that. So you see there's even some craters up at the North Pole and then you can see some of the northern ridges there as they curve around between 11 o'clock and 9 o'clock when you look at it as a clock face.

On slide number 53, we did actually image the exact North Pole. It took some trickery with the images, but we were able to bring out the actual pole. Slide number 54 shows a gridded map, this is, once again, the topographic map - the finally processed version and in this particular version of it the piece of Vesta's original crust we call (Vestaliataras) sticks out there quite nice at left of that image.

Now one of the things that it was responsible for on the mission was to oversee the geologic mapping of Vesta and if you go to slide number 55 you'll see the global geologic map that we made and the major units are color coded there are related to the geologic processes. Primarily the different impacts that dominated the surface and from that we were able to construct a geologic timescale, which you see on slide number 56 and you can see there at right it's basically a graph where at the bottom you have the formation of the solar system as 4.6 billion years ago all the way up to zero years of age at the present time. And then you see the numbers either on the left or the right showing the ages of which the different impact basins occurred.

We actually have two different scales because of two different calibration techniques we used to determine that, but nevertheless we have still be able to produce a geologic timescale consistent or similar to that which we produced on the Earth and for most of the other planets.

On slide 57 let's talk a little bit about Vesta's composition. On slide 58 you see a color-coded map there. That's the color imaging of the surface and you see sort of the greenish-yellow colors at bottom within the South Pole within those basins and that's very different from the more purplish colors that you see in the northern and mid-latitudes. And that's because those south polar basins have excavated the more iron magnesium rich minerals that make up (dioxinite).

And you can see on slide 55 particularly in the graph there at lower right there the points in that graph are all of the spectra from Vesta and those ovals - different colored ovals show you the composition of the three different meteorite classes that we think came from Vesta and you can see it's all basically included within there. So the (dioxinites) are the stuff from the deeper mantel of Vesta. The (eukrites) are the basaltic crusts and the howardites are an impact (unintelligible) made of the two. And it's exactly as it should be if that's how they were origin.

I'll skip slide 60 to go to slide 61. And you can see this is a view of the South Pole again and the red and yellow colors are very much consistent with the locations of those large impact at the South Pole and then the eukritic material is outside of that. So we did prove what had been suspected that Vesta is the host home of the HED meteorite.

Another discovery, we were looking for Olivine and we expected Olivine to be there in the mantel at the South Pole, but we didn't see much of it. However, we did discover it up in the northern crust at the northern latitudes exposed by some of the craters up there. And you see that on slide number 62. A couple of locations where we found evidence of Olivine. So it was very interesting it's having implications about the models of the interior.

We'll go down to slide number 63. If you can see it's just the absorptions by Oh and Pyroxene and it just shows that the water signature such as it is is not really water. It's the presence of OH tends to be consistent with areas where we have some of the darker material on the surface. And the idea is that carbonatious condrite that impacted on Vesta have delivered small amounts of hydrogen or OH to the surface.

Slide number 64 says preliminary GRaND map of Iron and this is just an example of what that instrument is allowing us to determine where there are concentrations of Iron and other minerals occurring.

Slide number 65 is Vesta's gravity and structure. And moving on to slide 66 you see the topographic map at the top and at the bottom is the gravity map. And you see even though it's offset a little bit that big red blob in the gravity map actually corresponds with the (Saliotera), our piece of original crust and you see the blue at the bottom of the gravity map is within those large basins at the South Pole and you see red at the top and at the time that map was made, you know, we hadn't imaged the northern hemisphere yet, but it shows that there wasn't a huge basin at the North Pole there's just some smaller craters up there.

So the implication from all of this gravity studies is shown on slide 67 and basically the interpretation is that Vesta did differentiate into a crust, mantel and core - that's what that sort of showing in that artist graphic. The models are shown on slide 68 and that's what we think the interior of Vesta would be like. You have the bluish crust, more dense mantel and probably a core about that big in the interior.

So in conclusion on slide 69 the results - Dawn successfully entered Vesta orbit on July 16, 2011. It did a survey orbit and there was no evidence of Vestan moons so we were able to go in much closer. We were able to identify two impact craters at the South Pole with central peaks. We found these unusual equatorial and northern latitude troughs which it turned out was evidence for a tectonic response of the formation of those large south polar basins. We accomplished the HAMO orbit to collect the mineralogical data from the (Vera spectrometer), which confirmed the length between Vesta and the ATD meteorite.

We dropped down to the LAMO orbit and we got our high resolution images and the elemental abundance data, which takes a really long time to tease out the information so that's still being worked on. We went back up to our second HAMO orbit between June and July of 2012. We imaged the North Pole and the northern high latitudes (unintelligible) so we could complete our geologic map. And we're still working on the data, so the Dawn spacecraft departed Vesta for Ceres back on September 5, 2012. And it will arrive at Ceres around March 5, 2015 - plus or minus a week. So less than a year from now, about half a year from now or so we'll actually start to see a bit about Ceres.

Now if you go to slide 70 it's really exciting because, you know, there was an announcement made not too long ago about some interesting results and you see a graphic of Ceres in the main belt with those unusual clouds coming off of it. And if you go to slide 71 this was from a press conference that occurred in January of this year. The European space agency's Herschel space telescope detected water molecules escaping from two geographic locations on Ceres of a rate of about 6 kilograms per second. This is detected when Ceres as close to the sun, which means it was warmer on the surface and the interpretation made is that it's either buried cometary ice or something we call crial-volcanism.

Crial volcanism refers to water mixed with some sort of an anti-freeze like a ammonia or methane, which when it comes out into the surface allows it to behave the way silicon lava flows do on earth. So it could be that there is some sort of unusual flow structures on the surface or maybe there's just a frozen ice body that's covered in regulative or perhaps just a comet impacted the surface and when it impacted it vaporized this material. Although it's strange that that would occur in two different locations at the same time. Anyway, whatever it is we will find out and we don't have much longer to wait. I forgot to update that slide too, but it's actually, as I said, Dawn arrives at Ceres right around March 5 of next year and then we'll see - we shall see at Ceres.

So at this point I'll say thank you for your attention. Ill stop and I'd be happy to take any questions.

Coordinator: Thank you. We will now begin the question and answer session. If you would like to ask a question please press star 1. Unmute your phone and record your name. If you need to withdraw your question you may press star 2. Again, to ask a question please press star 1. We will take a few moments for the questions to come in queue. Our first question is from (Stewart Meyers). Go ahead your line is open.

(Stewart Meyers): Hello, thanks for the presentation tonight.

Dr. David Williams: You're welcome.

(Stewart Meyers): I noticed when you were giving the lists of spacecraft that went, you know, imaged asteroids and stuff. I noticed that - I seem to recall that one of the Chinese probes imaged an asteroid as well.

Dr. David Williams: Okay, let's see. It's possible that one of them visited one. I made this slide back up around 2011 and 12 so if they did visit one it's possible that I just didn't keep it on there.

(Stewart Meyers): It was one of their lunar probes and then after it had finished it's mission it had enough fuel so they decided to send it out towards one of the outpoints.

(Dave) I actually - (Dave) here. I actually I just looked it up because I remember that too. It was (Chang Yi 2) after it finished it's lunar mission. They flown it the nearest asteroid - asteroid (Tutatus). It looked kind of like a peanut.

(Stewart Meyers): So, yes.

Dr. David Williams: Oh okay. Yes, you guys are right. Yes, I do remember that now. Yes, I just didn't get a chance to update the slide since I made it, but thank you for mentioning that to me. I can update the slide with that information.

(Stewart Meyers): You're welcome, bye.

Dr. David Williams: Other questions?

Coordinator: Again, as a reminder please press star 1 on your phone and record your name if you have a question. One moment please. We have a question from (Joseph Hulner). Go ahead your line is open.

(Joseph Hulner): Hello, I enjoyed the presentation very much. Thank you.

Dr. David Williams: Thank you very much.

(Joseph Hulner): What is the backup slide number two illustrating? The one with the small crater with the arrow pointing towards it

Dr. David Williams: All right, let's see here. Okay, that arrow is point to a crater that's been named (Claudia) and that is the location of a prime meridian for what we call the (Claudia) coordinate system. When Dawn got to Vesta we had the capability to improve the latitude-longitude coordinate system over that which was used by the Hubble Space Telescope and we needed to pick a crater of which to establish that. So they picked that small crater named (Claudia) and that's what we used to establish our system.

So that's why that slide is in there just in case anybody asked me about that. Interestingly enough there's been some discussion and disagreement between the Dawn science team and the International Astronomical Union about that crater. They - we are delivering the data to NASA's Planetary Data System in the original Hubble coordinate system and then telling people how they can convert to our own (Claudia) coordinate system, which we think is...

(Joseph Hulner): Thank you.

Dr. David Williams: You're welcome.

((David Prosper): This is actually (Dave) again. I have a question myself.

Dr. David Williams: Yes?

(David Prosper): Since we were checking out the first two largest asteroids - what about the third largest (Palace)? Are there any chances for a mission there? Is there any chance Dawn could get there after Ceres if there's still enough fuel left or is that outside of the possibilities?

Dr. David Williams: It won't be possible for Dawn to visit it. You know, during the course of the mission we've had a failure in one of our reaction wheels, actually two of them, and so when we get to Ceres we're going to have to use almost all of the hydrosene fuel onboard. And, you know, even though we use ion propulsion to go from body to body in the solar system you have to use the onboard hydrosene fuel to control and point the spacecraft to collect your data. And engineers figure that we're going to use up all of the hydrosene on the Dawn spacecraft just to complete the Ceres mission. So even though there will probably be ion fuel - Xenon fuel for the ion engine we can't really leave Ceres orbit because we wouldn't have any hydrosene to take any observations of any place else in the solar system.

Now the Dawn spacecraft, you know, when the mission was conceived was only to visit those two and I believe the orbit of (Palace) is different enough that it would be really hard to go to a third asteroid with this space craft anyway. So, you know, the scientific community is such that it always proposes missions to do specific things, visit specific locations and accomplish specific goals. I don't know that much about (Palace) but I don't think it's the same composition as these other two. I think the two end members, (Carbonacious C-type) Ceres and the V-type Vesta are to distinct end members.

I think (Palace) is probably S-type or something like that - I don't know for sure, but somebody would have to propose a specific mission to do that if they had enough scientific justification to do that. I know the people are thinking about doing missions to some of the iron asteroids or perhaps some of the other (unintelligible) types out there. But, yes, nothing has been proposed at this time to go to (Palace).

(David Prosper): Okay, cool. Thank you and we have time for one more question if we have anyone - anymore questions out there.

Coordinator: Our next question is form (John Burie). Go ahead, your line is open.

(John Burie): Thank you. I very enjoyed this webcast. It was very excellent. My question is the water reserves on Ceres - are they simply being gradually lost space?

Dr. David Williams: Well we're not quite certain what actually is there. The telescopic spectra tells us that a signature that water is there in some form, but it's not liquid water it may not even be ice. It could be something like what we geologists call philosilicates, which are clay minerals, but that was our expectation. However, you know, with that announcement back in January of the water vapor coming off in two distinct geographic regions is very puzzling and, you know, it's led a lot of people to think well maybe that there is buried ice reservoirs on Ceres. You know, all you need is a thin later of (regelate), you know, soil or fragmental material that you can be produced from impacts striking the crusts and you can cover that stuff and it'll be preserved from being lost by, you know, solar wind.

You know, the concept called the snow line in the solar system and the snow line is somewhere between Vesta and Ceres and if you're sunward of the snow line then liquid water won't be stable on one of these planetary bodies without atmospheres and then when you go outside that then water ides will be stable. Perhaps depending on what shape it's in. If it has some shadowing to protect it. Maybe a thin covering and then, of course, in the out solar system you have ice, you know, preserved under the surfaces of the moons the giant planets.

So we really don't know what it is that's there and that's why we're so excited about the Dawn mission arriving at Ceres. When we get our first close up look, you know, it'll be very interesting if we did find large quantities of water ides preserved on the surface because that would be an excellent space resource to, you know, help build a space fairing civilization and you don't have to go all the way to the outer solar system to do it. And, you know, if there's a source of heat there as well, well you know, life requires and it requires water and it requires organic material. So you would have two of the three key ingredients there. I don't want to get people's hopes up, but, you know, there's going to be a lot of very interesting findings coming when we finally get to Ceres.

(David Prosper): Cool.

Dr. David Williams: Are there any other questions?

(David Prosper): I think that's it for this evening. Can you hear me okay?

Dr. David Williams: Yes I can.

(David Prosper): Cool. I just lost track if I had muted myself or not - cool. Well that's all the time we have for this evening as well. So I want to thank the Night Sky Network members for your excellent questions and for calling in and, of course, a huge huge thanks to your Dr. Williams for giving us - or Dr. Dave - for giving us so much of your time and your really awesome presentation.

Dr. David Williams: Well it was my pleasure, thank you.

(Dave): You're welcome, thank you. Cool, so that's all for tonight. So you can find this telecom along with many others of our past telecons on the Night Sky Network under the astronomy activity section. Just search for telecom as the keyword. So tonight's presentation with a full audio and written transcript will be posted in the next couple of days. So good night everyone and keep looking up.

Dr. David Williams: Thank you very much.

Coordinator: That concludes tonight's conference. Thank you for participating. You may disconnect at this time.

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